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DEVELOPMENT OF LIGHT-ATTENUATING DEVICES (LADS) TO SIMULATE NIGHT VISIBILITY DURING DAYLIGHT

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U. S. Army
Research Institute for the Behavioral and Social Sciences

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To circumvent safety, evaluation, and logistics problems in nighttime training, ARI has developed light-attenuating devices (LADs) to simulate night visual conditions and allow daytime training. Both single-density and bidensity lenses have been developed for a variety of facemasks. This report documents ARI's role in developing and fabricating LADs and discusses potential applications for training.

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Using LADs to simulate night visibility for night training and testing may be more advantageous than actual night training for several reasons. First, safety: With single-density LADs, someone with full vision can monitor trainees' performance. Second, performance evaluation: Instructors working in daylight can better observe and evaluate trainees' performance. Third, convenience: Daylight is a more convenient time for many qualifications tests.

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Training and Education

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FOREWORD

This report documents the role of the Army Research Institute for the Behavioral and Social Sciences (ARI) in developing and fabricating light-attenuating devices (LADs). LADs are technological innovations that simulate night-illumination levels so that night training and testing can be conducted in daylight.

Since 1974, scientists at ARI have been involved in evaluating the concept of using simulated darkness for night training during daylight. To evaluate feasibility of this training concept, LADs have been developed to reproduce the essential features of night visual conditions.

In 1974 and 1975, a filter was fabricated to fit on a standard Army sun/wind/dust goggle to conduct research on nap-of-the-earth flight at Fort Rucker, Ala. In early 1977, outsert lenses were designed to fit over the M17 protective mask to conduct land navigation research at Fort Lewis, Wash. In winter 1977-78, the Basic Combat Training (BCT) Committee Group at Fort Jackson, S.C., conducted a field experiment to evaluate LADs as applied to training and testing night rifle marksmanship.

The LADs project has been accomplished jointly by ARI and Gentex Corporation (Omnitech Division) under contracts DAHC-19-77-M-0011 (J. Douglas Dressel as COTR) and DAHC-19-77-M-0049 (Paul R. Bleda as (COTR). Work reported was originated by the Aircrew Performance Work Unit by John P. Farrell under David Meister, in the Human Factors in Tactical Operations Technical Area under Aaron Hyman, and under Army Project 2Q162722A765, Night Operations Methodology. This report was prepared under Army Project 2Q162722A764, Training and Education.

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DEVELOPMENT OF LIGHT-ATTENUATING DEVICES (LADs)
TO SIMULATE NIGHT VISIBILITY DURING DAYLIGHT

BRIEF

Requirement:

To develop light-attenuating devices (LADs) that permit night or twilight training to take place during the daytime.

Product:

Coated and dyed plastic lenses that transmit precisely attenuated amounts of light have been fabricated and mounted in various existing Army facemasks, both as single-density lenses that transmit the same amount of light throughout and as bidensity lenses that are darker at the top. Tests and field trials indicate that wearers' perceptions and performances closely resemble those of actual night.

Utilization:

Use of LADs to simulate night training may provide more safety, as in tank cross-country driving or helicopter flight where an instructor has full vision, and better performance evaluation, as well as administrative convenience in scheduling training. Use of LADs for night rifle marksmanship training at Fort Jackson, S.C., was estimated to save appreciable time and ammunition.

DEVELOPMENT OF LIGHT-ATTENUATING DEVICES (LADs)
TO SIMULATE NIGHT VISIBILITY DURING DAYLIGHT

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DEVELOPMENT OF LIGHT-ATTENUATING DEVICES (LADs) TO SIMULATE NIGHT VISIBILITY DURING DAYLIGHT

INTRODUCTION

Tactics and doctrine in the modern Army have emphasized the concept of continuous operations, which specifies that military functions continue around the clock, under all weather conditions, and across different terrains. A continuous combat capability depends on an army's capacity to perform without letup, unhindered by darkness, reduced visibility, or extreme temperatures. The importance of a continuous operations capability is essential, mainly because the Soviets have adopted such a capability as the primary principle of their combat doctrine since the late 1950s.

The doctrine of continuous operations places new emphasis on night warfare. To conduct successful night missions, combat personnel must be trained to perform when visual cues are reduced. However, numerous administrative problems relating to safety, performance evaluation, and convenience arise when training and testing are held at night. To circumvent the limitations inherent in night training, scientists at the U.S. Army Research Institute (ARI) have developed light-attenuating devices (LADs) that simulate night visual conditions to allow training during daylight. This paper documents ARI's involvement in the development, fabrication, and evaluation of LADs.

The use of LADs during daylight may be more advantageous than actual night training in several respects. First, single-density LADs are safe to use, because trainees' performances can be monitored by a person with full vision. For example, during aviation, flight instructors not wearing LADs would be in a better position to manipulate dual controls to avoid potential hazards. Second, training effectiveness is enhanced because instructors can better observe and evaluate trainee performance. Thus, the corrective feedback to trainees is based on a more accurate and thorough account of their behavior. Third, many qualification tests are conducted more conveniently during daylight, allowing greater scheduling flexibility and minimizing the "dead" time spent waiting for darkness.

Other limited-visibility conditions with great tactical importance can be simulated with the LADs by varying the optical density (o.d.) of the filters. For example, future combat conditions most likely will emphasize the dawn and dusk periods, because the development of passive night-vision devices has reduced the tactical advantages once afforded by darkness. Although effective at night, passive night-vision devices become inoperative in twilight when the illumination level is too high for the image intensifiers but too low for good vision with the naked

eye. Because dawn and dusk are short and occur at widely separated parts of the day, it is difficult to train for them. By simulating twilight conditions using LADs, effective training could be conducted during most of the day.

The concept of using LADs for training purposes is not new. In the late 1940s, British researchers tried to simulate night visibility for aircraft crew trainees by circulating an opaquing fluid between twin-walled bubble canopies. However, this technique was never used widely because the uneven distribution of fluid resulted in uneven light attenuation (Lazo, 1974).

In the United States, various combinations of blue and amber filters as well as Polaroid materials have been used to train aircraft personnel. A blue and amber filter combination lowered light level, but for the instruments to be visible, one filter had to be applied to the trainee's goggles and the other to the cockpit windscreen. Unfortunately, this technique reduced the instructor's visibility, although to a lesser extent than the trainee's. The technique was abandoned when flight simulators for instrument and night flight were introduced. A neutral density filter was developed to simulate twilight and dusk for airborne visual reconnaissance teams (Porterfield & Self, 1971), but it was never used on a wide scale.

There were two attempts to simulate night conditions for infantry training, the first at Fort Benning, Ga., in the 1950s, and the second at Fort Sheridan, Ill., from 1968 through 1970. The first effort was cancelled before extensive testing was undertaken, but the second involved a more thorough development and evaluation program.

At Fort Sheridan, exposed X-ray film was inserted into the frame of the standard military sun/wind/dust goggle. Although exposed film attenuates light across all spectral regions, including infrared (I.R.) and ultraviolet (U.V.), it is difficult to obtain optical densities over 4.0 without the film becoming occluded. Some light scatter also occurs.

Preliminary tests at Fort Sheridan supported the concept of using LADs for night training during daylight but showed the need for an improved filter. Plastic filters containing carbon particles in colloidal suspension were developed, and eventually 7,000 lenses with an optical density of 5.5 were bought for extensive field tests. In 1970, however, problems with lens fogging from perspiration and with light scatter when the lenses faced the sun led to the project's termination. Those involved in that effort believed that such technological problems eventually could have been solved.

LADs PROGRAM AT ARI

At ARI, John P. Farrell initiated exploratory work on the development of the LADs concept in 1973. The technical specifications of various light-attenuating materials were investigated.

Investigations began with dual layers of Polaroid filters (Table 1). In the configuration used, one sheet remained stationary while the other was rotated to vary the level of attenuated light. However, this technique was rejected because of the inability to produce precise and uniform attenuation levels.

Photochromic materials that darken upon exposure to light were rejected because of the delay in the material's response time and because of poor attenuation in the infrared and ultraviolet regions.

Various filters with a glass substrate were rejected for safety reasons.

Significant expansion of the effort occurred in 1974, when it was decided that LADs must have the characteristics listed in Table 2 to achieve Army-wide acceptance.

Sandwich Goggles

John P. Farrell and Aaron Hyman developed the initial prototype of LADs using the frame of the standard Army sun/wind/dust goggle modified to provide light-tight ventilation. Farrell and Hyman combined several elements to produce attenuation with the correct spectral characteristics in the lenses. A neutral gray plastic lens for glare protection was the base onto which the other elements were affixed (Farrell, 1975). To the base were added (a) a layer of Scotch-tint film consisting of metallic particles deposited on plastic to attenuate infrared rays; (b) a Kodak Wratten #96 neutral density filter[1] to attenuate ultraviolet and visible light; and (c) a sheet of clear acetate to protect the other materials (see Table 3).

There were two versions of the sandwich type of LADs: a single-density and a bidensity lens. The single-density lens had a constant amount of attenuation across the entire visual field (5.3 o.d.). The bidensity lens had greater attenuation in the upper part of the lens (5.0 o.d.) than in the lower part (3.5 o.d.). To validate the overall attenuation produced by the sandwiched elements, the optical density was measured in a Cary model 14 spectrophotometer, and the readings were integrated against the photopic visual function.

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[1] Commercial designations in this report are given only in the interest of precision of reporting. Their use does not constitute indorsement by the U.S. Army Research Institute or the U.S. Army.

Table 1

Characteristics of Various Light-Attenuating Filters

Types	Effectiveness	Limitations
1. Exposed photographic and X-ray film	Poor to moderate	Hazy appearance
2. Colloidal carbon in plastic	Moderate	Hazy appearance
3. Rotating pairs of Polaroid lenses	Moderate	Difficult to obtain uniform attenuation and precise optical density
4. Photochromic material	Not tested	Transmits infrared and ultraviolet, slow response time
5. Flash protection helmet (for naval aviators) electrically activated	Good	Heavy, requires power source
6. Wratten filters in combination	Not tested	Transmits infrared
7. Wratten filters plus metallic film	Very good	Fragile, scratches easily, slight haze when facing sun
8. Evaporated metal	Excellent	Expensive, difficult to produce
9. Polycarbonate plastic with organic dyes and metallic coating	Excellent	None

Table 2

Desired Characteristics of LADs

Optical	Physical
• Attenuation of light in the ultraviolet and infrared regions for safety reasons	• Wide, unobstructed field of view
• Minimal distortion	• Light-tight seal to the face
• Relatively neutral attenuation in the visible range	• Compatibility with corrective lenses and standard gear
• Uniform attenuation across the visual field	• Light weight
• Adequate simulation of various illumination levels (i.e., full moon, quarter moon, etc.)	• Durable lenses with abrasion-resistant coating
	• Adequate ventilation system
	• Antifogging coating
	• Outer protective cover
	• Relatively inexpensive

Table 3

Sandwich Goggle Version of LADs

Characteristics of filter	Characteristics of facemask	Limitations
Neutral density gray glare lens of standard Army sun/wind/dust goggle serves as base to which sandwich combination of lenses is affixed	Standard military sun/wind/dust goggle provides relatively inexpensive, comfortable, and durable facemask	Fragile, easily scratched, and damaged by temperatures above 110^{o}
Layer of Scotch-tint film added to gray glare lens to reflect potentially harmful infrared light	Ventilation holes covered with black foam rubber of photographic tape to reduce light leakage	Ventilation system not satisfactory, fogging occurs on inside of LADs unless dessicant bags heated at regular intervals
Wratten #96 neutral density filters of colloidal carbon dispersed in gelatin provides neutral attenuation of ultraviolet and visible light	Two dessicant bags inserted between the frame and lens over each eye and extended into the temporal area to absorb perspiration	Lenses are subject to minor light scatter when facing the sun with hazy appearance resulting
Bidensity lens with 5.0 optical density in the upper portion of lens and 3.5 in the lower, so that pilots could read their instrument panel. Also, single-density LADs with 5.5 density throughout		Relatively expensive
Layer of clear acetate added to inside surface of Wratten filters as protection from scratching		Cannot be worn over corrective lenses

The single-density and bidensity versions of the sandwich goggle LADs were field tested by Farrell for infantry tasks at Fort Ord, Calif., and aviation tasks at Fort Rucker, Ala., in 1974. The infantry tests included distance estimation, target detection, and terrain walking. The aviation tests consisted of helicopter maneuvers such as 360° and 45° bank turns, hovering, obstacle avoidance, and obstacle detection. The results of these preliminary field tests were encouraging, because performance with the LADs appeared to be degraded to the same extent as performance under actual night conditions. Unfortunately, the initial mockup version of these LADs was too fragile for more extensive field testing because Wratten filters scratch easily and must not be exposed to temperatures above 110°F.

Evaporated-Metal Coated Lenses

Evaporated metal lenses were investigated to try to overcome the difficulties inherent in the Wratten filters. Light-attenuating filters are produced by heating a metal such as silver or the alloy inconel in a vacuum chamber and depositing a thin layer of the metallic particles on a substrate such as glass. This type of filter attenuates well in the ultraviolet and infrared regions and, in general, meets the required characteristics listed in Table 2. Four prototype lenses were produced with contractor support from Gentex Corporation (Omnitech Division). The filters were fabricated by depositing silver on both sides of a plastic substrate (butyl acetate), because optical densities over 4.0 are difficult to obtain in a single coating with this technique. An antiscratch coating was applied to protect the metal, and both single-density and bidensity lenses were produced.

Farrell field tested these LADs for aviation use at Fort Rucker. Although performances obtained with this version corresponded with those obtained with the sandwich goggle, subjects preferred the evaporated metal lenses because of their greater clarity. Pilots also favored the single-density over the bidensity lens; this response was surprising because the bidensity lens was specially designed to facilitate reading the instrument panel. However, most pilots indicated that they found the bidensity goggles distracting and said they preferred to "keep their eyes outside the cockpit" and to query the copilot when instrument information was needed. Unfortunately, the evaporated metal lenses were too expensive for more extensive field testing.

Outsert Lenses

The next stage of development began in early 1976, monitored by Douglas Dressel with design direction from Aaron Hyman. These scientists fabricated a neutral attenuating lens of dyed polycarbonate plastic with a metallic coating designed to fit as an outsert on the standard Army protective mask (M17A1). Table 4 provides a more detailed description of this type of LAD.

Table 4

Outsert-Lens Version of LADs

Characteristics of filter	Characteristics of facemask	Limitations
Polycarbonate plastic lens dyed with a neutral density organic compound having an optical density of 2.0	Lens is pear-shaped, about 4 inches in diameter	Curvature of lenses produced some visual distortion
Silver metallic deposit in upper portion of the lens extending to 1 inch from the lens bottom	Fits on to an ABC-M17 Field Protective Mask (designed for nuclear, biological, chemical (NBC) attack)	Wearing a protective mask is uncomfortable and inappropriate in certain situations
Silver deposit used to reduce transmittance by a density of 1.5 in the ultraviolet, visual, and infrared regions of the spectrum	Fits into a metal retaining clip on eyelens; clip effectively seals the rubber mounting to the lens	
Single-density and bidensity LADs of varying densities formed by combining two different lens together		
Outsert lens has distortion of one-eighth diopter		

Both single-density and bidensity lenses of various densities and density combinations were fabricated. The LADs were field tested in the summer of 1977 with elements of the 9th Infantry Division at Fort Lewis, Wash. (Peters, Bleda, & Fineberg, 1979). A bidensity LAD having a density of 5.5 in the upper part and 4.0 in the lower part was used in the test for safety reasons--navigators could easily check their footing. Not surprisingly, the findings indicated that performance during actual night was significantly degraded in terms of navigation speed and accuracy. Performances obtained using the LADs were between those found in daylight and at night. It appeared that the bidensity safety feature allowed navigators with LADs to travel slightly faster than navigators who performed at night. However, it was the consensus of those present during the research that a single-density LAD would yield results comparable to those found for actual night.

Welder's Goggles. In response to a field request from Fort Jackson, S.C., ARI scientists, with contractor support from Gentex Corporation (Omnitech Division), developed a light-attenuating goggle that can accommodate trainees who wear helmets and corrective lenses (Bleda & Johnson, 1978). This version of the LADs was designed to provide a relatively quick and inexpensive solution to a night-fire problem at Fort Jackson. Consequently, these LADs were fabricated using a conventional welder's goggle facemask from American Optics Corporation (product #488) and a #12 and #13 welder's shade plate produced by Gentex Corporation. The welder's plates were made of polycarbonate plastic filters containing an organic dye with a metallic gold coating on one of the lenses to filter out potentially harmful infrared and ultraviolet rays. Table 5 gives the technical specifications of welder's goggle LADs.

POTENTIAL APPLICATIONS

In early 1978, a series of field tests at Fort Jackson assessed the feasibility of applying LADs to train and test night rifle marksmanship during daylight (Bleda, 1979; Bleda & Labrozzi, 1979). The results of the first of these tests validated the comparability of the various optical densities of the LADs to different moon phases in the specific training environment at Fort Jackson. Comparability was defined in terms of the percentage of trainees who qualified for record; that is, who achieved a specific number of hits on pop-up targets at 25 and 50 m.

Follow-up research compared the immediate (2 to 3 hours) performance transfer and long-range retention (7 weeks) derived from practice and record fire with the LADs to performance in actual nighttime. The results demonstrated that the LADs' performance index was as effective as the actual night performance index. Although one limitation of the welder's goggle LAD is that it restricts peripheral vision, it appears that a wide field of view is not essential for the night rifle marksmanship application of the LADs.

Table 5

Welder's Goggle Version of LADs

Characteristics of filter	Characteristics of facemask	Limitations
Standard welder's #12 or #13 molded shade plate lens made of organically dyed polycarbonate plastic	Commercial welder's goggle face-mask (American Optics product #488) made of soft green vinyl material	Restricted field of view
Evaporated hard metallic (gold alloy) coating on one side of the plate to either reflect or absorb (filter out) potentially harmful infrared and ultra-violet light	Indirect ventilation through plastic louvers that eliminate light leakage by creating light traps	Not completely light-tight
Acetate sheet shade lens with tinted gray base	Lens compartment can be easily disassembled or removed for exchange of filter combinations	Uncomfortable for some users with relatively small head sizes
Clear cover plate made of poly-carbonate plastic with scratch-resistant coating	Foam urethene pads have been added as temple flaps and along the edges that come in contact with the cheekbones, forehead, and nose to increase light tight-ness. Composition gasket of trenolic-impregnated fiber and plastic serves as seal between facepiece and frame. Metal spring separates lens	
Hydrosorb coating to reduce fogging on inside of lens		

Two field experiments at Fort Knox, Ky., evaluated the feasibility of using LADs to train night tank-driving and weapons disassembly/assembly. Trainees practiced either at night or with the LADs during daylight before being tested at night. With regard to tank-driving, the results indicated that reductions in errors as a function of prior practice were comparable for both the night- and LAD-trained groups. Moreover, the findings for weapons disassembly/assembly task revealed that subjects trained with LADs required an average of 83 fewer seconds to complete the task than did their conventionally trained counterparts. These results indicate that the application of LADs to training during daylight for these two night tasks was successful (Bleda & Bauer, 1979).

It is important to note that LADs cannot be applied directly to certain training areas. For example, small amounts of focused or diffused light (such as that emitted by the luminous dial of a compass or the instrument panel of a vehicle) cannot be seen with LADs, because the filters attenuate light by several orders of magnitude. For this reason, LADs may not be useful for training and testing tasks performed at night with limited levels of artificial light. In many training situations, however, these problems can be circumvented through procedural changes (e.g., increasing the intensity of the light source) or technological modifications to the LADs (e.g., using bidensity lenses).

Eventually, the concept of using simulated rather than actual conditions of darkness may prove of great value to the Army. LADs may provide a safe, convenient, and cost effective way to develop a continuous operations capability. The LADs program can continue to expand in several ways. The program can develop an even greater arsenal of different types of these devices for application to diverse training tasks. In this regard, LADs can be fabricated for use with different sighting mechanisms, periscopes, windows, and so on. With various modifications, LADs can be used to simulate not only night but also other conditions of reduced visibility, such as smokescreens or dawn-dusk twilight conditions. In addition to its training applications, LADs may serve to fill an important role in the conduct of basic research. That is, LADs can be a tool for investigating human performance capabilities during reduced visibility.

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1 USA Topographic Lab, Ft Belvoir, ATTN: STINFO Center
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1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATS-CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TE
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEX-GS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTS-OR
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-DT
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-CS
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1 HQ, USMC, Commandant, ATTN: Code MPI-20-28
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1 USCG, Psychol Res Br, DC, ATTN: GP 1/62
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1 US Marine Corps Liaison Ofc, AMC, Alexandria, ATTN: AMCGS -F
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1 HQUSA Aviation Sys Cmd, St Louis, ATTN: AMSAV-ZDR
2 USA Aviation Sys Test Act., Edwards AFB, ATTN: SAVTE-T
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA TEM
1 USA Air Mobility Rsch & Dev Lab, Moffett Fld, ATTN: SAVDL-AS
1 USA Aviation Sch, Res Tng Mgt, Ft Rucker, ATTN: ATST-T-RTM
1 USA Aviation Sch, CO, Ft Rucker, ATTN: ATST-D-A
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1 HQ, DARCOM, Alexandria, ATTN: CDR
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1 US Military Academy, West Point, ATTN: Ofc of Milt Ldrshp
1 US Military Academy, West Point, ATTN: MAOR
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1 NAVAIRSTA, Norfolk, ATTN: Safety Ctr
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1 AFHRL (AS) WPAFB, OH
2 AFHRL (DOJZ) Brooks AFB
1 AFHRL (DOJN) Lackland AFB
1 HQUSAF (INYSD)
1 HQUSAF (DPXXA)
1 AFVTG (RD) Randolph AFB
3 AMRL (HE) WPAFB, OH
2 AF Inst of Tech, WPAFB, OH, ATTN: ENE/SL
1 ATC (XPTD) Randolph AFB
1 USAF AeroMed Lib, Brooks AFB (SUL-4), ATTN: DOC SEC
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1 AF Log Cmd, McClellan AFB, ATTN: ALC/DPCRB
1 Air Force Academy, CO, ATTN: Dept of Bel Scn
5 NavPers & Dev Ctr, San Diego
2 Navy Med Neuropsychiatric Rsch Unit, San Diego
1 Nav Electronic Lab, San Diego, ATTN: Res Lab
1 Nav TrngCen, San Diego, ATTN: Code 9000-Lib
1 NavPostGraSch, Monterey, ATTN: Code 55Aa
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1 NavTrngEquipCtr, Orlando, ATTN: Tech Lib
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1 US Dept of Justice, DC, ATTN: Drug Enforce Admin
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1 Ministerie van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands